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INTERNATIONAL CONFERENCE/WORKSHOP ON SMALL FATIGUE
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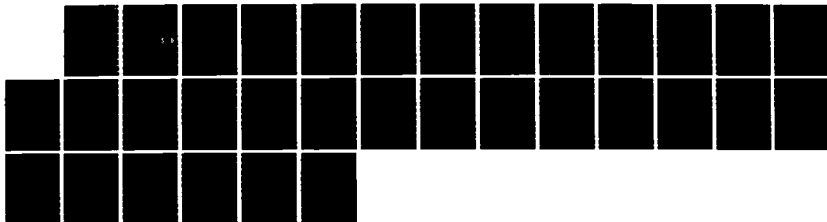
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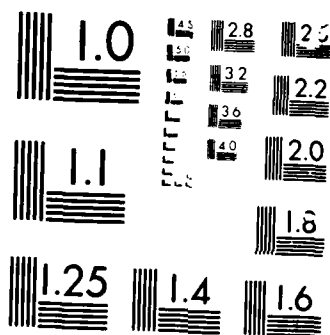
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Final Report

to

U.S. Army Research Office
Materials Science Division
P.O. Box 12211
Research Triangle Park, N.C. 27709-2211
attention: Dr. George Mayer

on

THE SECOND INTERNATIONAL CONFERENCE/WORKSHOP
ON SMALL FATIGUE CRACKS
5-10 January 1986

Contract No. DAAG29-85-G-0110

prepared by

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and

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(Conference Chairmen)

on behalf of

United Engineering Trustees, Inc.
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<p>This document provides a description and technical summary of the Second International Engineering Foundation Conference/Workshop on Small Fatigue Cracks, held in Santa Barbara, California, 5-10 January 1986. It provides a current assessment of the pertinent issues with respect to definition, differences in behavior compared to long cracks, environmental effects, "driving forces" for small crack extension, intrinsic thresholds, and the application of small crack methodology to life prediction and alloy design. A listing of the conference participants and the technical program are appended to the report.</p>					
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**THE SECOND INTERNATIONAL CONFERENCE/WORKSHOP
ON SMALL FATIGUE CRACKS**

R. O. Ritchie and J. Lankford

FORWARD

This document constitutes the Final Report on the Second International Conference/Workshop on Small Cracks, held under the auspices of the Engineering Foundation at the Hotel Miramar, Santa Barbara, California, on January 5-10, 1986, with Drs. R. O. Ritchie and J. Lankford as Conference Chairmen. In addition to the Engineering Foundation, the meeting was co-sponsored by grants from the U.S. Air Force of Scientific Research, the U.S. Army Research Office, the National Science Foundation, and the U.S. Office of Naval Research.

ABSTRACT

This document provides a description and technical summary of the Second International Engineering Foundation Conference/Workshop on Small Fatigue Cracks, held in Santa Barbara, California, 5-10 January, 1986. It provides a current assessment of the pertinent issues with respect to definition, differences in behavior compared to long cracks, environmental effects, "driving forces" for small crack extension, intrinsic thresholds, and the application of small crack methodology to life prediction and alloy design. A listing of the conference participants and the technical program are appended to the report.

1. INTRODUCTION

The Second International Conference/Workshop on Small Fatigue Cracks was held at the Hotel Miramar, Santa Barbara, California, on 5-10 January 1986 under the auspices of the Engineering Foundation. The conference was organized by Dr. Robert O. Ritchie, Professor of Metallurgy, University of California, Berkeley, and Dr. James Lankford, Institute Scientist, Southwest Research Institute, San Antonio, Texas, who acted as the Conference Chairmen. The meeting was the second in a series of Engineering Conferences on Small Fatigue Cracks; the first was held at Asilomar, California, in January 1980 with Drs. M. E. Fine and R. O. Ritchie as chairmen.

Sponsorship, principally in the form of travel support for foreign participants, and fellowships for graduate student attendees, was provided by the Air Force Office of Scientific Research, the Army Research Office, the National Science Foundation, and the Office of Naval Research, in addition to the Engineering Foundation.

The conference was attended by most of the world's leading experts on the small crack problem. In all, 77 researchers participated, coming from Austria (2), England (11), France (1), Japan (4), Sweden (1), West Germany (3) and the U.S. An attendance list is given in the appendix to this report. Also appended to the report is a copy of the technical program, which consisted of 26 invited and 15 contributed talks. The program was divided into 8 half-day sessions, each with 3 or 4 invited presentations, with

remaining time devoted to discussion, and 2 half-day sessions for contributed papers. The topics of the sessions concerned crack initiation and Stage I crack growth, role of microstructure, fracture mechanics characterization, role of environment, near-threshold behavior, experimental techniques, micromechanics and modelling, and engineering applications.

The technical content of the meeting was extremely good, with presentations generally of unusually high standard. In addition, there was ample time for discussion (by design), which resulted in a lively and informative meeting. Significant advances were made, both at the fundamental level, where many of the critical issues were brought sharply into focus, and with respect to practical engineering application, where the potential importance of small crack methodology was demonstrated to the industrial user.

A summary of the technical progress reviewed at the meeting is given below, based on the closing comments of the conference chairmen. This summary, together with written versions of the majority of the presentations, is due to be published by The Metallurgical Society of AIME later this year, under the title of "Small Fatigue Cracks", edited by R. O. Ritchie and J. Lankford.

2. CONFERENCE SUMMARY

In providing a technical summary of this meeting, it is important to ask how far the understanding of the behavior of small

cracks, and related topics, has progressed since the first of the Engineering Foundation conferences on Small Fatigue Cracks at Asilomar in January 1980. Clearly, the definition of the many mechanisms of crack closure and their role in the development of a threshold for long cracks is now well established. Furthermore, there are now far more results available on the related crack growth behavior of small cracks, although compared to long crack data the total number of papers reporting new information on small flaws is still not large. Similarly, although several models have been developed to describe small crack behavior, the total number of models is still relatively small. However, very significant progress has been made in the past six years in the sharper definition of critical issues, and in the fact that small crack methodology has begun to be appreciated in technological design and lifetime prediction, as evidenced by use of small crack data in the U.K. for turbine blade applications. Described below are our impressions of the highlights of this progress.

The Small Crack Problem

The small crack problem is in essence one created by fracture mechanics through a breakdown in the similitude concept at small crack sizes. For example, it was shown that crack tip strain fields for large and microstructurally-small fatigue cracks, driven by nominally equivalent cyclic stress intensities, are qualitatively and quantitatively dissimilar. It is thus a problem of defining a flaw

size-independent "crack driving force" to account for observations that small cracks can propagate at rates different from those of corresponding long cracks at the same nominal driving force. In the large majority of cases, small crack growth rates exceed those of long cracks, although there is evidence in steels of a mild reverse effect. Following initiation, small cracks are observed to grow at stress intensities below the long crack threshold; some extend with decaying growth rates until arrest, while others propagate quite rapidly to merge with long crack behavior. The problem therefore has practical significance, because damage-tolerant fatigue lifetime computations are invariably based on long crack data. As overall life is most influenced by low growth rate behavior, the accelerated and sub-threshold extension of small flaws can lead to potentially dangerous over-predictions of life.

Definition of a Small Crack

Numerous adjectives describing various types of small crack were proposed, although a consensus began to emerge. For example, the distinction between (three-dimensional) small flaws and (two-dimensional) short flaws, the latter being small in all but one dimension, clearly is of importance. Short flaws are generally through-thickness cracks, no smaller than 50 μm , which are created artificially by removing the wake material from long through cracks. Their behavior appears to be dominated, like that of large cracks, by the cyclic stress intensity factor ΔK (for small-scale yielding),

corrected by considerations of crack closure. Naturally-occurring small flaws, conversely, often approach microstructural dimensions, and although their behavior is still largely affected by closure, several other factors, including crack shape, enhanced crack tip plastic strains, and local arrest at grain boundaries, are of comparable significance.

Useful qualifiers remain microstructurally-, mechanically- and physically-small (or short), which pertain respectively to cracks small compared to microstructural dimensions, to the scale of local plasticity, and simply to cracks of a size less than 0.5 to 1 mm. In addition, fatigue cracks were also described, with reference to environmental effects, as chemically-small, as described below. Each of these classes of small flaw is associated with particular phenomena which primarily distinguish it from long crack behavior (Table I). For example, for mechanically-small flaws, characterization in terms of elastic-plastic fracture mechanics (e.g., through the use of $\Delta CTOD$ or ΔJ) may help resolve differences in growth rates behavior between long and small cracks. On the other hand, for physically-small flaws, allowance for differences in the magnitude of crack closure (e.g., through the use of ΔK_{eff}) appears to be the predominant correlating factor. In the case of microstructurally-small flaws, all these factors may be important, plus others associated with local inhomogeneities in the microstructure, non-uniform growth, retardation at grain boundaries, and so forth.

Table I. Classes of Small Fatigue Cracks

Type of Small Crack	Dimension	Responsible Mechanism	Potential Solution
Mechanically-small	$a \lesssim r_y^a$	excessive (active) plasticity	use of ΔJ $\Delta CTOD$
Microstructurally-small	$a \lesssim d_g^b$ $2c \lesssim 5-10 d_g$	crack tip shielding enhanced $\Delta \epsilon_p$ crack shape	probabilistic approach
Physically-small	$a \lesssim 1 \text{ mm}$	crack tip shielding (crack closure)	use of ΔK_{eff}
Chemically-small	up to $\sim 10 \text{ mm}^c$	local crack tip environment	

^a r_y is plastic zone size or plastic field of notch.

^b d_g is critical microstructural dimension, e.g., grain size, a is the crack depth and $2c$ the surface length.

^cCritical size is a function of frequency and reaction kinetics.

In particular, the microstructurally-small, rapidly growing crack corresponds to a three-dimensional crack whose plastic zone is less than the key microstructural dimension, which in most cases is the grain size. Thus, the crack tip tends to operate as it would in a single crystal preferentially oriented for operation of the relevant crack extension mechanism. In addition, the crack front encompasses relatively few grains, so that growth is not averaged over many disadvantageously oriented grains. The latter is probably a major factor in distinguishing small cracks from short through-thickness

cracks, whose fronts must necessarily sample many grains. It further provides an explanation why crack tip shielding alone is generally sufficient to rationalize behavior of the short through crack.

Origins of Differences between Long and Small Crack Behavior

Several major factors were identified which are primarily responsible for differences in long and small crack behavior (Table I). Of particular significance was the varying contribution of crack tip shielding, with size of the crack wake, in locally reducing the effective driving force experienced at the tip. Such shielding arises in fatigue from crack closure, and to a lesser extent from crack deflection, and was shown to be diminished at small crack sizes. However, for microstructurally-small cracks, it is now apparent that closure does not provide the entire solution (although uncertainties in experimental measurement make this question difficult to resolve). There is now considerable evidence that, additionally, such flaws are impeded locally by grain boundaries, influenced by non-uniform growth, and may experience higher cyclic plastic strains at their tips. Finally, it was shown that differences in local crack tip environment with crack size provide the source of the chemically-short crack effect, as described below.

Environmental Effects

One of the most complex issues involved in the small crack problem is associated with (liquid) environmental effects. As

outlined by Prof. R. P. Wei the chemically-short crack may still propagate 1.5 to several hundred times faster than long cracks subjected to the same mechanical driving force. Moreover, it may be somewhat larger than the microstructurally- or mechanically-short flaw, as short crack behavior has been reported for crack sizes upwards of 10 mm. (Precise definition of the size range for chemically-short cracks depends upon several factors but is principally controlled by frequency and reaction kinetics). The discrepancy in behavior is attributed to differences in local crack tip chemical environment and conditions. The critical issues thus pertain to the determination of crack tip conditions, as a function of crack length, in terms of the coupled processes of fluid transport and chemical/electrochemical reactions within the crack, and the determination of the origin of the environmentally-enhanced cracking rates in relation to the hydrogen embrittlement and film rupture/dissolution mechanisms.

"Driving Force" for Small Crack Propagation

Several authors sought improved field characterizing parameters to describe the driving force for small crack advance (Table I). Although parameters such as $\Delta\sigma$ and $\Delta\epsilon_p$ have been suggested, only those parameters that can be measured globally, yet define (at least nominally) local conditions, were reviewed critically. For mechanically-small cracks, where the extent of local plasticity is comparable with crack size, elastic-plastic fracture mechanics

solutions were proposed through the use of ΔJ and ΔS (the strain energy density). While certainly appropriate for taking account of excessive plasticity *ahead* of the tip, it should be noted that J is a nonlinear elastic parameter, and thus cannot similarly account for the vital influence of wake plasticity (*prior plastic*) zones *behind* the tip. To allow for such wake effects, which principally cause crack closure, the adoption of a closure-corrected ΔK_{eff} ($= K_{max} - K_{cl}$, where K_{cl} is the closure stress intensity) appears to be a suitable approach for physically-small cracks and cracks emanating from notches. For microstructurally-small flaws, however, such deterministic treatments may simply not apply, as initial cracking may center on local preferential growth sites ("soft spots") in the microstructure. Here a probabilistic approach may be the optimum treatment to describe the behavior of such tiny flaws.

Intrinsic Thresholds

There is now good evidence that intrinsic threshold cyclic stress intensities may exist for long fatigue cracks. By subtracting out the contribution from crack closure through the use of the ΔK_{eff} parameter, threshold values at low load ratios approach those at high load ratios where closure effects are minimal. Similarly, intrinsic thresholds may exist for physically- and mechanically-short cracks, of magnitude comparable with the effective long crack value. For microstructurally-small cracks, however, the question of an intrinsic threshold may not be meaningful. Here the

"fatal" flaws are the ones that initiate first at local "soft spots" in the microstructure. As their dimensions are well below any continuum approximation, characterization in terms of a material parameter clearly would be inappropriate. Further, in light of presented evidence suggesting the invalidity of ΔK within this flaw size regime, it may be more appropriate to consider a threshold stress, rather than a stress intensity, for microstructurally-small flaws.

Small Crack Methodology in Life Prediction and Design

For physically- or mechanically-small cracks, the adoption of small crack methodology in life prediction analyses would appear to be feasible by mere extension of the current damage-tolerant procedures to smaller crack sizes through the use of ΔK_{eff} , or an equivalent elastic-plastic characterizing parameter. Such an approach would greatly enhance projected lifetimes, as computations are dominated by the regimes where the crack is small and advancing slowly. Conversely, for the reasons outlined above, descriptions of the extension of microstructurally-small flaws will not be generally amenable to deterministic analyses which rely on (continuum) material parameters, and should be treated with probabilistic approaches.

Small Crack Considerations in Alloy Design

From an alloy design perspective, the study of small cracks and associated long crack thresholds has resulted in a far clearer

understanding of the various contributions to fatigue resistance. Moreover, it has led to the realization that microstructural features which benefit resistance to the growth of (long) cracks may have an entirely different influence on crack initiation and small crack growth. To impede long crack growth, the primary mechanisms are **extrinsic**, whereby mechanical, microstructural, and even environmental mechanisms are utilized to reduce locally the crack driving force. Here, promotion of crack tip shielding, principally through crack closure and deflection, provides the most potent effect under cyclic loading. Conversely, to impede crack initiation and the early growth of microstructurally-small cracks, where shielding effects are minimized, the primary mechanisms are **intrinsic**. For example, fine grain sizes were reported offer best resistance to crack initiation and small crack growth in many alloys, yet in these same materials it is the coarse grain structures which promote the roughest crack paths and hence provide greatest resistance to long crack growth (through crack deflection and roughness-induced closure).

In essence, the ideal alloy design approach is to clean-up the material for optimum resistance to crack initiation, incorporate small, randomly oriented grains to inhibit small crack growth, and then to add microstructural "crack stoppers" to impede long crack growth. It may also be possible to minimize the small crack problem by incorporating texture, so that as few grains as possible are

oriented for easy crack extension relative to a known uniaxial loading axis.

APPENDIX

1. List of Conference Participants
2. Technical Program

SECOND INTERNATIONAL WORKSHOP ON SMALL FATIGUE CRACKS

The Miramar Hotel
Santa Barbara, California
January 5-10, 1986

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SECOND INTERNATIONAL WORKSHOP ON SMALL FATIGUE CRACKS

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SECOND INTERNATIONAL WORKSHOP ON SMALL FATIGUE CRACKS

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SECOND INTERNATIONAL WORKSHOP ON SMALL FATIGUE CRACKS

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SECOND INTERNATIONAL WORKSHOP ON SMALL FATIGUE CRACKS

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ENGINEERING FOUNDATION CONFERENCES

SECOND INTERNATIONAL WORKSHOP ON SMALL FATIGUE CRACKS

The Miramar Hotel
Santa Barbara, California
January 5-10, 1986

Cosponsored by

U.S. National Science Foundation
Office of Naval Research
Air Force Office of Scientific Research
U.S. Army Research Office

ENGINEERING FOUNDATION CONFERENCES

SECOND INTERNATIONAL WORKSHOP ON SMALL FATIGUE CRACKS

The Miramar Hotel
Santa Barbara, California
January 5-10, 1986

FINAL PROGRAM

Sunday, January 5, 1986

3:00 p.m.-9:00 p.m. REGISTRATION AND CHECK-IN

6:00 p.m. DINNER

9:00 p.m.-11:00 p.m. SOCIAL HOUR

Monday, January 6, 1986

7:30 a.m. BREAKFAST

9:00 a.m.-9:15 a.m. Introduction/Opening Remarks
Dann Hall, Engineering Foundation
Chairmen: R. O. Ritchie, U.C. Berkeley
J. Lankford, SWRI

9:15 a.m.-12:30 p.m. CRACK INITIATION AND STAGE I CRACK GROWTH
Chairman: M. E. Fine, Northwestern University

9:15 a.m.-9:45 a.m. "Distributions of Small Crack Sizes in Fatigued Copper
Single Crystals"
B. T. Ma & C. Laird, University of Pennsylvania

9:45 a.m.-10:00 a.m. Discussion

10:00 a.m.-10:30 a.m. "Fatigue Crack Formation in Copper"
P. Neumann, Max Planck Institute, Dusseldorf

10:30 a.m.-10:45 a.m. Discussion

10:45 a.m.-11:15 COFFEE BREAK

11:15 a.m.-11:45 a.m. "Fatigue Crack Initiation and Short Crack Propagation"
F. H. Heubaum, I. B. Kwon and M. E. Fine, Northwestern
University

11:45 a.m.-12:00 Noon Discussion

12:00 Noon-12:30 p.m. General Discussion

12:30 p.m. LUNCH

2:00 p.m.-5:00 p.m. AD HOC SESSION

5:00 p.m.-6:00 p.m. SOCIAL HOUR

6:00 p.m. DINNER

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Monday, January 6, 1986 (continued)

7:00 p.m.-10:00 p.m.

ROLE OF MICROSTRUCTURE

Chairman: J. Lankford, SWRI

7:00 p.m.-7:30 p.m.

"Propagation Behavior of Short Cracks in Ti-Alloys"
L. Wagner, J. K. Gregory, A. Gysler, and G. Lutjering,
Tech. University, Hamburg-Harburg.

7:30 p.m.-7:45 p.m.

Discussion

7:45 p.m.-8:15 p.m.

"The Relevance of Microstructural Influences in the Short
Crack Regime to Overall Fatigue Resistance"
C. W. Brown, B. P. Research, and J. E. King, University of
Nottingham, U.K.

8:15 p.m.-8:30 p.m.

Discussion

8:30 p.m.-9:00 p.m.

"Overview on the Role of Microstructure"
J. Lankford, SWRI

9:00 p.m.-9:15 p.m.

Discussion

9:15 p.m.-10:00 p.m.

General Discussion

10:00 p.m.-11:00 p.m.

SOCIAL HOUR

Tuesday, January 7, 1986

7:30 a.m.

BREAKFAST

9:00 a.m.-12:30 p.m.

FRACTURE MECHANICS CHARACTERIZATION

Chairman: J. C. Newman, Jr., NASA, Langley

9:00 a.m.-9:30 a.m.

"Effect of Large Plastic Strains on Crack Closure in
Fatigue"
N. E. Dowling and N. S. Iyyer, V.P.I. & S.U.

9:30 a.m.-9:45 a.m.

Discussion

9:45 a.m.-10:15 a.m.

"In Search of a Field Parameter to Characterize the
Mechanical Driving Force for Small Cracks"
S. J. Hudak and K. S. Chan, SWRI

10:15 a.m.-10:30 a.m.

Discussion

10:30 a.m.-11:00 a.m.

COFFEE BREAK

11:00 a.m.-11:30 a.m.

"An Analysis of Crack Closure for Small Cracks"
J. C. Newman, Jr., NASA, Langley

11:30 a.m.-11:45 a.m.

Discussion

11:45 a.m.-12:30 p.m.

General Discussion

12:30 p.m.

LUNCH

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Tuesday, January 7, 1986 (continued)
2:00 p.m.-5:00 p.m. AD HOC SESSION

5:00 p.m.-6:00 p.m. SOCIAL HOUR

6:00 p.m. DINNER

7:00 p.m.-10:00 p.m. ROLE OF ENVIRONMENT
Chairman: R. P. Gangloff, Exxon

7:00 p.m.-7:30 p.m. "The Role of Crack Depth in Determining Crack
Electrochemistry and Crack Growth"
A. Turnbull, National Physical Laboratory, U.K., and
R. C. Newmann, UMIST, U.K.

7:30 p.m.-7:45 p.m. Discussion: R. G. Ballinger, MIT

7:45 p.m.-8:15 p.m. "Small Crack Interactions: The Hydrogen Embrittlement
Perspective"
R. P. Gangloff, Exxon, and R. P. Wei, Lehigh University

8:15 p.m.-8:30 p.m. Discussion: W. W. Gerberich, University of Minnesota

8:30 p.m.-9:00 p.m. "Potential Role of Film Rupture Mechanisms on
Environmentally-Assisted Small Crack Growth"
F. P. Ford, General Electric and S. J. Hudak, SWRI

9:00 p.m.-9:15 p.m. Discussion: D. J. Duquette, RPI

9:15 p.m.-10:00 p.m. General Discussion & Summary: R. M. Pelloux, MIT &
P. M. Scott, Harwell, U.K.

10:00 p.m.-11:00 p.m. SOCIAL HOUR

Wednesday, January 8, 1986
7:30 a.m. BREAKFAST

9:00 a.m.-12:30 p.m. NEAR-THRESHOLD BEHAVIOR
Chairman: R. O. Ritchie, U.C. Berkeley

9:00 a.m.-9:30 a.m. "A Comparison of Short and Long Fatigue Crack Behavior
in the Near-Threshold Regime"
W. Yu and R. O. Ritchie, University of California, Berkeley

9:30 a.m.-9:45 a.m. Discussion

9:45 a.m.-10:15 a.m. "Short Fatigue Crack Behavior in Relation to Three-Dimension
Aspects and Crack Closure Effect"
A. Pineau, Ecole des Mines de Paris, France

10:15 a.m.-10:30 a.m. Discussion

10:30 a.m.-11:00 a.m. COFFEE BREAK

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Wednesday, January 8, 1986 (continued)

11:00 a.m.-11:30 a.m.	"The Growth of Short Fatigue Cracks in High Strength Nickel Alloys" C. J. Beevers, University of Birmingham, U.K.
11:30 a.m.-11:45 a.m.	Discussion
11:45 a.m.-12:30 p.m.	General Discussion
12:30 p.m.	LUNCH
2:00 p.m.-5:00 p.m.	AD HOC SESSION
5:00 p.m.-6:00 p.m.	SOCIAL HOUR
6:00 p.m.	DINNER
7:00 p.m.-10:00 p.m.	<u>EXPERIMENTAL TECHNIQUES</u> Chairman: D. L. Davidson, SWRI
7:00 p.m.-7:25 p.m.	"High Resolution Techniques for the Study of Small Fatigue Cracks" D. L. Davidson and J. Lankford, SWRI
7:25 p.m.-7:40 p.m.	Discussion
7:40 p.m.-8:05 p.m.	"Small Crack Growth Studies with a Surface Acoustic Wave Technique" D. V. Nelson, B. D. London and H. H. Yuce, Stanford University
8:05 p.m.-8:20 p.m.	Discussion
8:20 p.m.-8:45 p.m.	"Study of the Growth of Small Tensile Cracks: A Procedure Involving Crack Initiation under Far-Field Compression" S. Suresh, Brown University
8:45 p.m.-9:00 p.m.	Discussion
9:00 p.m.-9:25 p.m.	"Studies of Small Crack Growth Using Ultrasound Techniques" R. Stickler, University of Vienna, Austria
9:25 p.m.-9:40 p.m.	Discussion
9:40 p.m.-10:00 p.m.	General Discussion
10:00 p.m.-11:00 p.m.	SOCIAL HOUR

Thursday, January 9, 1986

7:30 a.m.	BREAKFAST
9:00 a.m.-12:30 Noon	<u>MICROMECHANICS AND MODELLING</u> Chairman: S. Suresh, Brown University

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Thursday, January 9, 1986 (continued)

9:00 a.m.-9:30 a.m.	"Modelling of Propagation and Non-Propagation of Small Fatigue Cracks" K. Tanaka, Kyoto University, Japan
9:30 a.m.-9:45 a.m.	Discussion
9:45 a.m.-10:15 a.m.	"Small Fatigue Flaws: Effects of Crack Geometry and Crack-Tip Plasticity" C. F. Shih and S. Suresh, Brown University
10:15 a.m.-10:30 a.m.	Discussion
10:30 a.m.-11:00 a.m.	COFFEE BREAK
11:00 a.m.-11:30 a.m.	"Short Crack Theory" J. Weertman, Northwestern University
11:30 a.m.-11:45 a.m.	Discussion
11:45 a.m.-12:30 p.m.	General Discussion
12:30 p.m.	LUNCH
2:00 p.m.-3:45 p.m.	<u>CONTRIBUTED PAPERS I</u> Chairman: R. J. Bucci, Alcoa
2:00 p.m.-2:15 p.m.	"A CTOD Model for Microcrack Initiation in Brass Under SCC Conditions" O. Buck and R. Ranjan, Iowa State University
2:20 p.m.-2:35 p.m.	"Crack Arrest by Self Stress at Notches" H. O. Fuchs, Stanford University
2:40 p.m.-2:55 p.m.	"Characteristics of Cracking Behavior of Metals and Notch Sensitivities in Fatigue" H. Nisitani and K.-I. Takeo, Kyushu University, Japan
3:00 p.m.-3:15 p.m.	"Closure and Growth Behavior of Short Fatigue Cracks at Notches in 3% Silicon Iron" K. Ohji and Y. Nakai, Osaka University, Japan
3:20 p.m.-3:35 p.m.	"Predicting the Special Growth Rates of Small Cracks Using a Unified Model" A. K. Miller, A. Obabueki and C. H. Lee, Stanford University
3:40 p.m.-3:55 p.m.	"Influence of Long Range Order on Crack Initiation and Growth" N. S. Stoloff, RPI
5:00 p.m.-6:00 p.m.	SOCIAL HOUR
6:00 p.m.	DINNER

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Thursday, January 9, 1986 (continued)

7:00 p.m.-10:00 p.m.

CONTRIBUTED PAPERS II

Chairman: R. O. Ritchie, U.C. Berkeley

7:00 p.m.-7:15 p.m.

"Crack Tip Field Parameters for Large and Small Cracks"
K. S. Chan, SWRI

7:20 p.m.-7:35 p.m.

"The Growth of Short Fatigue Cracks in Ti Alloys IMI550 and IMI318"
R. K. Bolingbroke, E. A. Pickering and J. E. King,
Nottingham University, U.K.

7:40 p.m.-7:55 p.m.

"K_{eff} Rationalization of Short Crack Behavior:
Environmental and Microstructural Influence"
A. Zeghloul and J. Petit, ENSMA, France

8:00 p.m.-8:15 p.m.

"The Breaking Load Method--A Quantitative Testing Approach
for Assessing Early Macrocrack Growth"
R. J. Bucci, R. L. Brazill and J. R. Brockenbrough, Alcoa

8:20 p.m.-8:35 p.m.

"Surface Microplastic Deformation of Al 2219-T851"
W. L. Morris, B. N. Cox and M. R. James, Rockwell Science
Center, Thousand Oaks

8:40 p.m.-8:55 p.m.

"Relevance of Short Fatigue Crack Growth Data for Damage
Tolerant Analysis of Aircraft"
A. F. Blom, Aeronautical Research Institute of Sweden

9:00 p.m.-9:15 p.m.

"Small Fatigue Cracks Growing from a Notch"
W. N. Sharpe and J. J. Lee, Johns Hopkins University

9:20 p.m.-9:35 p.m.

"An Effect of Micro-structure on Short Cracks in
Eutectoid Steel."
A. W. Thompson, Carnegie-Mellor University

9:40 p.m.-9:55 p.m.

"Mixed Mode Small Crack Growth"
C. T. Hua and D. W. Worthem, University of Illinois

10:00 p.m.-11:00 p.m.

SOCIAL HOUR

Friday, January 10, 1986

7:30 a.m.

BREAKFAST

8:30 a.m.- 12:15 Noon

ENGINEERING APPLICATIONS

Chairman: B. Tomkins, UKAEA

8:30 a.m.-9:00 a.m.

"Short Crack Methodology Related to Integrity Assessment
of Components in the Power Generation Industry"
T. C. Lindley, CERL, U. K. and B. Tomkins, UKAEA, U.K.

9:00 a.m.-9:15 a.m.

Discussion

9:15 a.m.-9:45 a.m.

"Small Cracks: Relevance to Component Integrity"
R. Jeal, Rolls Royce, U.K.

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Friday, January 10, 1986 (continued)

9:45 a.m.-10:00 a.m. Discussion

10:00 a.m.-10:30 a.m. "Engineering Applications of Small Crack Fatigue Properties"
S. Usamai, Hitachi, Japan

10:30 a.m.-10:45 a.m. Discussion

10:45 a.m.-11:15 a.m. General Discussion

11:15 p.m.-12:15 p.m. SUMMARY/CLOSING SESSION

Chairmen: J. Lankford, SWRI
R. O. Ritchie, U.C. Berkeley

Closing Remarks: R. J. Bucci, Alcoa
R. O. Ritchie, U.C. Berkeley

12:15 Noon LUNCH

ADJOURNMENT

END

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